20-009690

City of Bremerton NPDES Sediment Monitoring Report

Beak Consultants Incorporated
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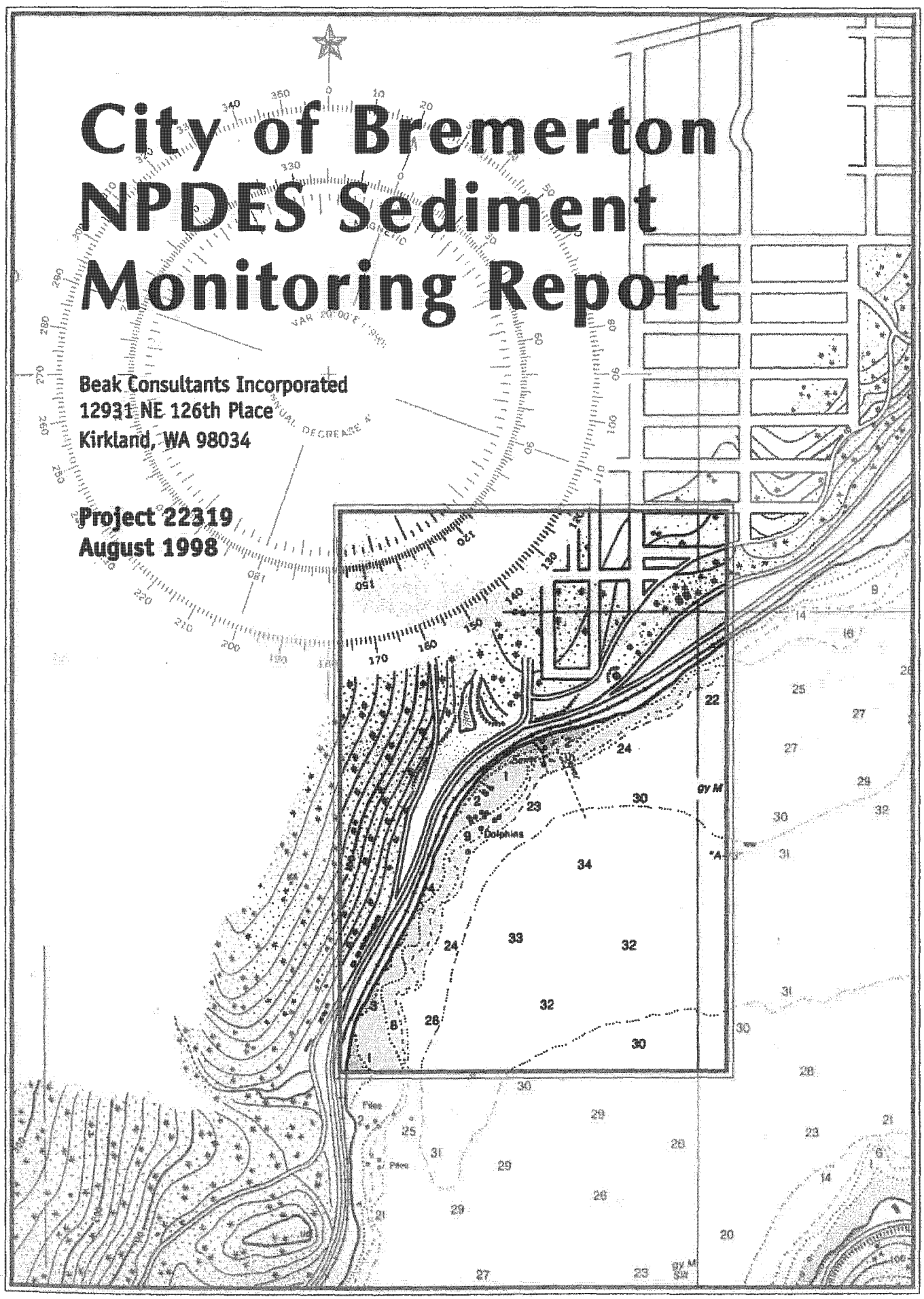
Project 22319
August 1998



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1.0 INTRODUCTION

1.1 Purpose

The City of Bremerton operates a Wastewater Treatment Plant (WWTP) located on Oyster Bay Road in the southwestern portion of Bremerton, Washington. The City is authorized to discharge WWTP effluent into Sinclair Inlet by its NPDES (National Pollutant Discharge Elimination System) Waste Discharge Permit No. WA-002928-9. Section S11 of the permit requires sediment monitoring at the WWTP outfall. The authority to require this sediment baseline monitoring comes from the Water Pollution Control Act, Chapter 90.48 RCW, and Chapter 173-204 WAC, the Sediment Management Standards (SMS)(Washington State Department of Ecology, 1995a).

1.2 Scope and Objectives

The NPDES Permit requires that a baseline sampling and analysis plan (SAP) be developed and approved by Washington State Department of Ecology (Ecology) prior to conducting sediment monitoring. The SAP (Beak Consultants 1995) was submitted to Ecology in June, 1995 and was reviewed by Ecology in 1996. In response to Ecology's comments on the SAP and discussions between Ms. Cathy McNair of Beak Consultants and Ms. Kathy Bragdon-Cook of Ecology in 1998, revisions to the SAP were made in the form of a letter from Ms. McNair to Ms. Bragdon-Cook dated 22 April 1998. The SAP was approved with these revisions by Ecology in April 1998.

The revised sampling and analysis plan addresses all sediment monitoring requirements and contingencies required by section S11 of the NPDES permit and specifies the methods that were used to conduct the sampling and analyses discussed in this report. The SAP was developed in compliance with the *Washington State Sediment Management Standards* (SMS)(WAC 173-204) (Washington State Department of Ecology, 1995a), guidance outlined in the *Sediment Source Control Standards User Manual* (Washington State Department of Ecology 1993a), and the *Draft*

Sediment Sampling and Analysis Plan Appendix (SAPA) (Washington State Department of Ecology, 1995b).

As described in the Sediment Source Control Standards User Manual the intent of the baseline monitoring requirement:

" is only to determine whether currently there are exceedances of [Sediment Quality Standards] SQS in the vicinity of the discharge, and whether they appear to be caused by the discharge. Baseline monitoring is not intended to accurately delimit the area over which there are exceedances of SQS, or to definitively tie those exceedances to the discharge. Baseline monitoring should be able to detect exceedances of SQS near the discharge and then to determine whether such exceedances are of greater magnitude near the discharge or of a more general, area-wide nature, which might suggest contaminant inputs from other local sources." (Washington Department of Ecology, 1993a).

In accordance with this intent and the specific procedures outlined in the SAP, the objectives of this project are to:

1) Collect ten sediment samples near the WWTP outfall
2) Perform chemistry analyses for all contaminants identified in the SMS
3) Perform confirmatory biological (bioassay) tests on any samples which exceed the SMS Sediment Quality Standards - Chemical Criteria (SQS)
4) Evaluate the testing results and make a determination if there are exceedances of SMS chemical or biological criteria near the discharges
5) Determine, if SQS criteria are exceeded, whether the exceedances are of greater magnitude near the discharges or are of a more general, area-wide nature.

A summary of information regarding the site history has been included in Section 2.0 of this report. Section 3.0 provides a summary of the materials and methods specified in the SAP and utilized during the course of this project. Section 4.0 presents the results of the chemical analyses, and a brief discussion of the results as they relate to the SMS. There has not been an extensive effort to determine the source of the contaminants, or to definitively tie the sediment monitoring results to input from the wastewater discharges. Section 5.0 presents the conclusions drawn from the monitoring results.

2.0 SITE BACKGROUND

2.1 Site Description

The City of Bremerton wastewater treatment plant (WWTP) is located on Oyster Bay Road in the southwestern portion of the city and discharges wastewater into Sinclair Inlet (Figure 2-1). The WWTP receives domestic sewage from residential and light commercial activities in the City of Bremerton, and Kitsap County Sewer District Number 1. There are numerous combined sewer tributaries to the WWTP and a large portion of all combined sewage (sanitary sewage combined with storm water) is received and treated at the facility (Washington Department of Ecology 1993b). In addition, the facility receives domestic and industrial wastewater from Puget Sound Naval Shipyard (PSNS). The domestic wastewater from PSNS includes wastewater from onshore chemical toilet facilities and saline wastewater from toilet facilities aboard the vessels. The industrial wastewater from PSNS includes pretreated wastewater from the industrial wastewater treatment facility.

Since July 1986, the Bremerton WWTP has discharged secondary-treated effluent. The multi-port diffuser outfall, currently used by the Bremerton WWTP to discharge wastewater to Sinclair Inlet, was originally built for the Charleston WWTP (Tetra Tech, 1988). The effluent is discharged through a 36-inch diameter outfall pipe which extends 450 feet offshore and terminates with a 120-foot long diffuser. The 570-foot long outfall extends from the shoreline near the intersection of State Road 3 and State Road 304 and discharges at a location southwest of PSNS (Figure 2-2).

N

SCALE: 1:25,000

SOUNDINGS IN FEET AT MEAN LOWER LOW WATER

CITY OF BREMERTON
NPDES SEDIMENT MONITORING

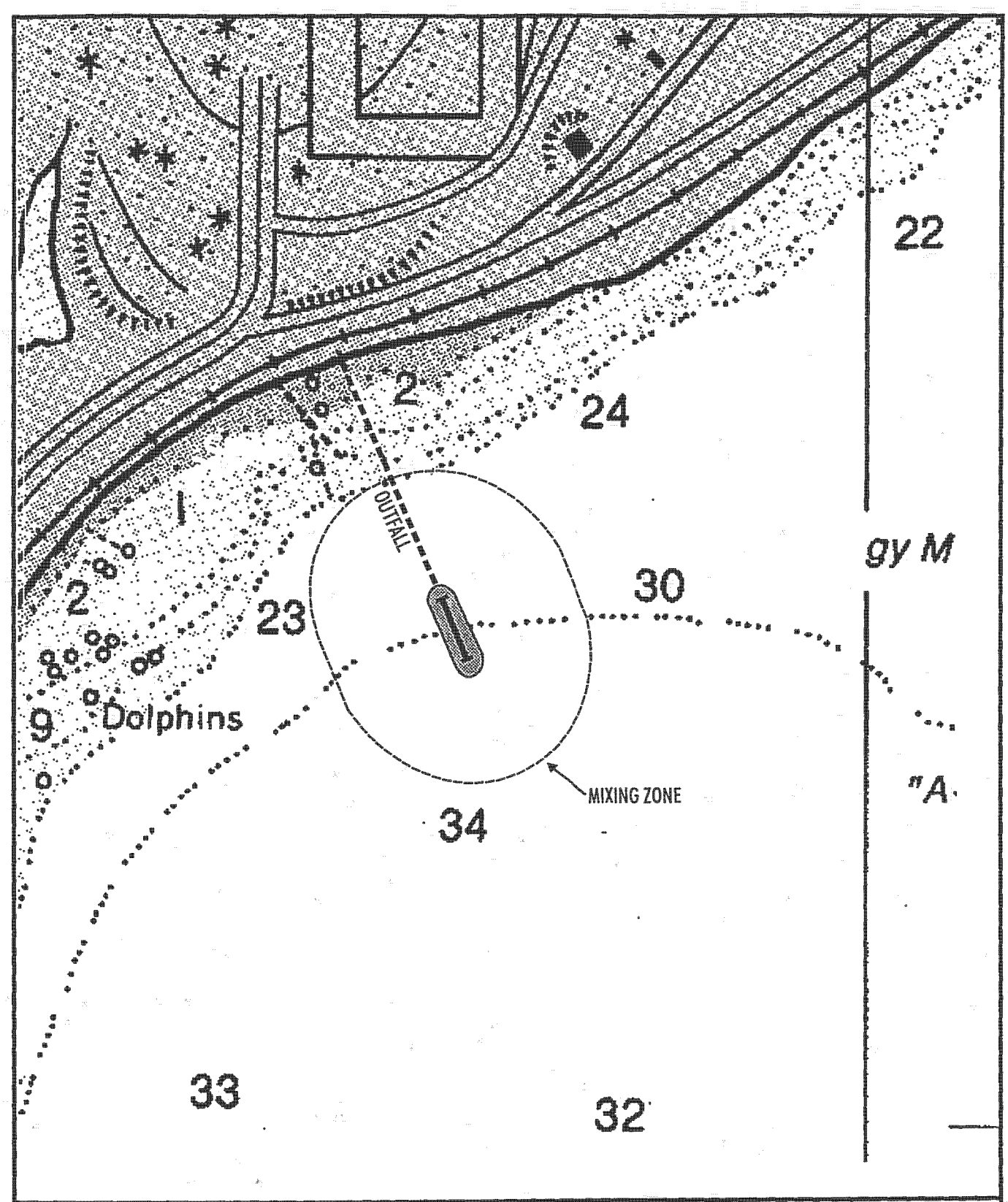
FIGURE 2-1

VICINITY MAP - SINCLAIR INLET/BREMERTON, WA

SOURCE REFERENCE: NOAA CHART 18449 - PUGET SOUND SEATTLE TO BREMERTON

PROJECT NO.: 22319.700	18 AUGUST 1998
2319-1-1.CDR/VGP	CHECKED: GME

beak



0 250 500

N

SCALE: 1:3000 (1"=250')

SOUNDINGS IN FEET AT MEAN LOWER LOW WATER

CITY OF BREMERTON
NPDES SEDIMENT MONITORING

FIGURE 2-2

SITE MAP - BREMERTON WWTP OUTFALL

SOURCE REFERENCE: NOAA CHART 18452 - SINCLAIR INLET

PROJECT NO.: 22319.700	18 AUGUST 1998
2319-1-2.CDR/VGP	CHECKED: GME

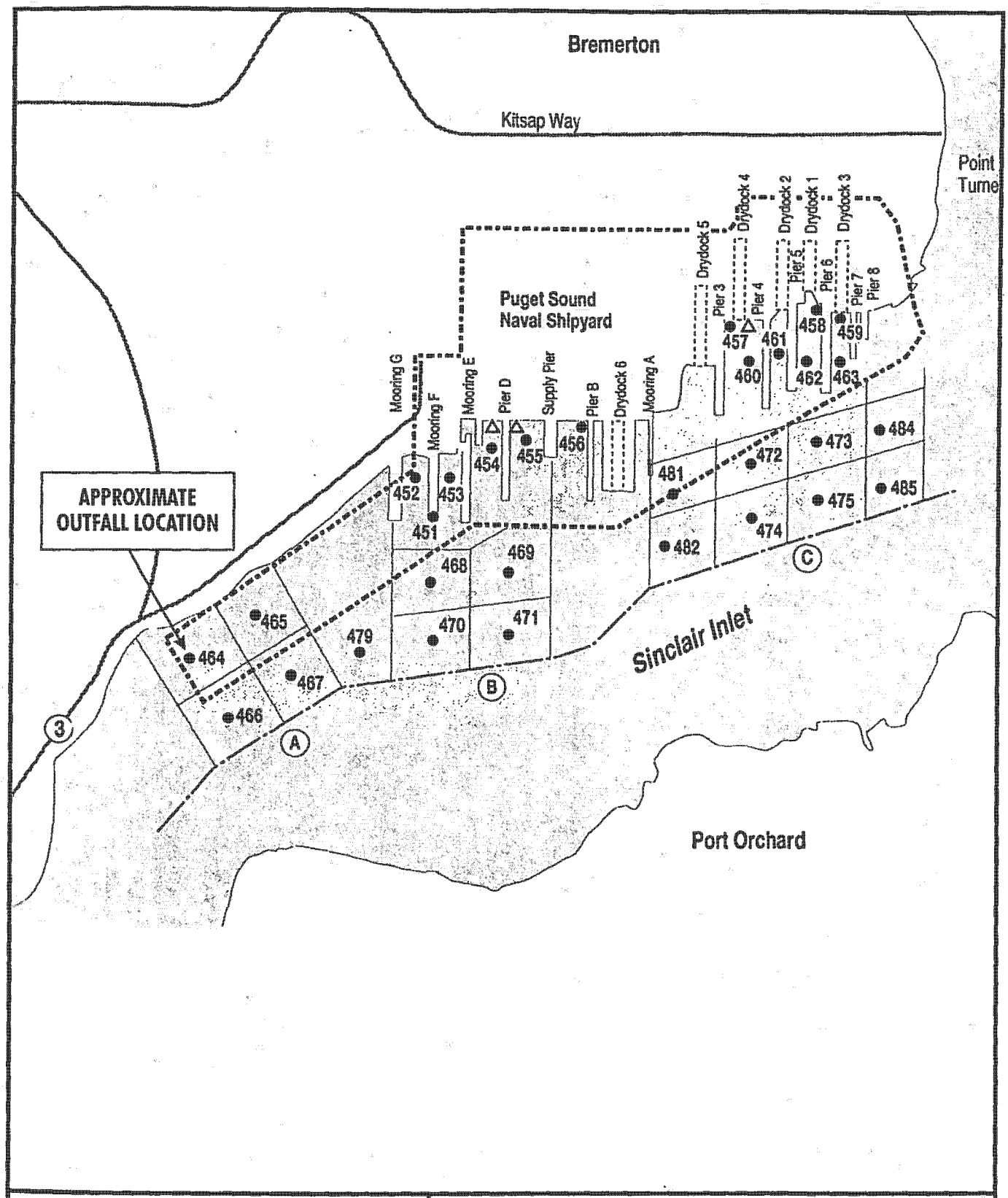
beak

2.2 Sediment Characteristics

Since there are other potential sources of contaminants in the vicinity of Bremerton's outfall, an understanding of previously collected sediment data is important. Sediment data collected in the last five years in Sinclair Inlet were found in one published document. Data collected in the past 10 years was also found from two sources. The most recent and significant study was conducted by URS Consultants for the U.S. Navy in 1994. The sediment data were collected as part of a remedial investigation/ feasibility study for the PSNS. The report for the initial phase of work is entitled: *Phase I Technical Memorandum- Remedial Investigation/ Feasibility Study (RI/FS)- Operable Unit B- Puget Sound Naval Shipyard- Bremerton, Washington*, and was published in December 1994 (URS Consultants, 1994). Additional information on Sinclair Inlet sediments and environmental conditions was found in: *Sinclair and Dyes Inlets Action Program: Initial Data Summaries and Problem Identification* (Tetra Tech, 1988). However, the sediment data included in this report are all greater than five years old and only a limited amount of data near the Bremerton outfall were reported. The Ecology Ambient Monitoring Program also has a sediment monitoring station (Station 34) in Sinclair Inlet approximately 625 yards to the ENE of the outfall diffuser (Figure 2-1). Sediment chemistry data from this station is discussed in Section 4.0 below.

Since the URS work is the most recent and most extensive it was used as the basis for this summary. The marine portion of the RI/FS included meteorological data collection, water quality monitoring, a sedimentation rate study, collection and analysis of English Sole tissue, a caged mussel study and sediment chemistry and bioassay analyses.

One of the mussel growth stations (#488) was placed approximately 1000 feet from the Bremerton outfall (Figure 2-3). Several English Sole were collected during trawls in the vicinity of the outfall (trawl #494). The findings of these two studies did not reveal any statistically significant differences between the samples near the outfall and the other stations in Sinclair Inlet.



Approximate Shipyard Boundary

Approximate Mid-Channel Location

(B) Sampling Grids

△ Discharge

● Sediment Sampling Stations

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CITY OF BREMERTON
NPDES SEDIMENT MONITORING

FIGURE 2-3

1994 - PSNS SEDIMENT TEST STATIONS

SOURCE REFERENCE: URS CONSULTANTS 1994

PROJECT NO.: 22319.700	18 AUGUST 1998
2319-4-1.CDR/VGP	CHECKED: DBH

beak

The sedimentation rate study was conducted by collecting three sediment cores and dating sections of the cores by analysis of the lead 210 isotope. The probable accumulation rate of sediments in Sinclair Inlet, based on the Pb^{210} dating, is 0.42 to 0.43 $g/cm^2/yr$. The report suggests that this would result in a bulk sedimentation rate of somewhere between 0.5 and 0.75 cm/yr.

Four sediment sampling stations were placed in the general vicinity of the Bremerton outfall. The coordinates/positions of the sampling stations were not reported in the technical memorandum, only figures with the approximate locations of the samples were provided. Based on the "sediment test station location" figure, one of the stations (#464) appears to be in the immediate vicinity of the outfall discharge point. Three other stations (#465, #466, #467) were all located within approximately 1200 feet of the outfall (Figure 2-3).

Total organic carbon concentrations at these four stations ranged from 1.9 to 3.3 percent. The portion of fine-grained sediments (<63 micron diameter) at these stations was quite high. The percent fines at these stations ranged from 91 to 96 percent, compared with a range of 40 to 95 percent for all other samples.

Chemical analysis of the sediments collected at these four stations revealed an exceedance of SQS concentrations for mercury. Mercury concentrations of the four stations ranged from 0.86 to 1.20 mg/kg compared with a concentration range of 0.01 to 4.20 mg/kg for all 38 samples collected. Mercury was found at levels exceeding SQS criteria at all but four of the stations sampled. At the four stations near the outfall, all other SMS chemicals with numerical criteria were found at concentrations below SQS criteria or were not detected.

Amphipod, echinoderm larval and juvenile polycheate bioassays were conducted on each of the test sediments. Due to the high proportion of fine-grained material in the sediments, *Ampelisca abdita* was used for the amphipod bioassay. The reference sediment used for evaluation of these bioassays was collected from Holmes Harbor on Whidbey Island. The station nearest the outfall (#464) passed SQS criteria for all three bioassays. However, each of the other three stations failed SQS criteria for one of the three bioassays. Station 466 had a statistically different mortality than the reference sediment for both the amphipod and juvenile polychaete bioassays but exceeded the SQS criterion for only the amphipod bioassay. Stations 465 and 467 exhibited a statistically significant increase in mortality compared with the reference sediment for only the polycheate bioassay. Both stations 465 and 467 exceeded the SQS criterion for the juvenile polychaete bioassay.

The important finding of this study, in relation to the City of Bremerton WWTP discharge, is that although there is an SQS exceedance for mercury in the sample collected at the discharge point, the sediment did not exhibit significant mortality in the bioassays. Since elevated concentrations of mercury appear to be a widespread in Sinclair Inlet it is likely that the City's outfall is not the primary source of this contaminant.

2.3 Effluent Characteristics

The Bremerton WWTP is designed for a monthly average flow of 7.6 million gallons per day (MGD) a maximum monthly average flow of 10.1 MGD and a peak influent flow of 29.5 MGD. Under average monthly operating conditions the plant discharges 5.9 MGD through the outfall (CH^{2}M Hill, 1992).

Based on the current NPDES permit, effluent limitations on the total suspended solids (TSS) discharged are: maximum weekly average of 3790 lbs/day and a monthly average of 2527 lbs/day. Plant operation data from January 1988 to October 1992 show an average monthly TSS discharge

ranging from 250 to 1480 lbs/day with an approximate mean monthly discharge of 530 lbs/day (Washington Department of Ecology, 1993b).

Ecology evaluated the effluent concentrations and dilution occurring in the receiving water during the development of the NPDES fact sheet. After applying appropriate statistical analyses and EPA guidance, it was determined that chlorine, mercury and copper present a reasonable potential to exceed state water quality standards. The NPDES permit therefore contains effluent limits for chlorine, copper and mercury. There are no effluent limits for toxic organic compounds. Priority pollutant organic analyses of the effluent is conducted annually, priority pollutant metals analyses are conducted bi-monthly.

Priority pollutant metals analysis conducted in March, 1995 by the Municipality of Metropolitan Seattle (METRO) environmental lab found effluent copper concentration of 10.8 mg/l and zinc concentration of 17 mg/l. Mercury was not found at a concentration above the detection limit (0.2 ug/l). Organic analyses of the effluent conducted during March found only two (chloroform, Bis(2-ethylhexyl) phthalate) of over 130 compounds at quantifiable concentrations. Chlorinated hydrocarbons, pesticides and PCBs were not detected (Municipality of Metropolitan Seattle, 1995).

3.0 MATERIALS AND METHODS

3.1 Sampling and Testing Methodology

The methodology and purpose for sampling is described in detail in the *City of Bremerton, Washington Wastewater Treatment Plant Sediment Baseline Sampling and Analysis Plan* (Beak Consultants Incorporated, 1995) as revised by a letter from Ms. McNair to Ms. Bragdon-Cook dated 22 April 1998, mentioned above. The intent of the methodology set forth in the SAP was to determine if there are exceedances of SQS near the outfalls and, if so, to determine whether such exceedances are of greater magnitude near the discharge or are of a more general, area-wide nature. The methods for sample collection, preparation and analyses are based on the Puget Sound Estuary Program (PSEP) protocols (Puget Sound Estuary Program 1986, 1995, 1996a-d) and the interpretive criteria used were those specified in the SMS.

Recently deposited sediments were collected from each sampling station. All retained samples has penetration depths of greater than 10 cm, as specified in the April 22, 1998 letter to Ecology. Sampling stations were located such that each sample was spatially unique; samples were not composited before analysis. All samples were collected using identical collection procedures and decontamination protocols, and all samples were analyzed in the same manner. The analytical methods used were those specified in the SMS and related guidance documents (PSEP, 1989a, 1989b); thus, the resulting data are comparable to both the SMS criteria and to other data collected and analyzed with similar protocols and methods. Laboratory Quality Assurance/ Quality Control (QA/QC) checks included duplicate, triplicate and standard reference material analyses. Special cleanup procedures and methods were employed as necessary to ensure that analytical detection limits were below the SQS chemical criteria. The materials and methods specified in the SAP were strictly adhered to during the sample collection and analysis. A summary of the sample collection and analyses is provided in the following sections.

3.2 Sampling Station Locations

Ten sediment samples were collected during the sampling effort. Five sampling stations were located to the east of the WWTP outfall, and five to the west of the outfall (Figure 3-1). The two stations closest to the outfall on the east and west, were located within the acute mixing zone of the outfall, at about the mid-point of the diffuser. The remaining stations were spaced at 200 foot intervals starting with these two stations, along a line parallel to the shoreline, as specified in the SAP (Beak Consultants Incorporated, 1995). The collection of sediment from an ambient station was specified in the SAP. However, this station was not established and sampled, based on discussions with Ecology as outlined in the April 22, 1998 letter to Ecology mentioned above. This was due to the fact that adequate baseline sediment data from Sinclair Inlet in the vicinity of the outfall was available from a number of sources.

As is typical, five to eight acceptable sediment grabs with a van Veen sampler were required at each station to obtain sufficient sediment volume for both chemical and potential bioassay testing. Owing to the effect of wind, current and instrumentation errors on vessel positioning, all acceptable sediment grabs fell within a 12-foot radius of each other. All of the samples collected near the wastewater outfall were collected within 15 feet of the planned sampling station (Figure 3-1).

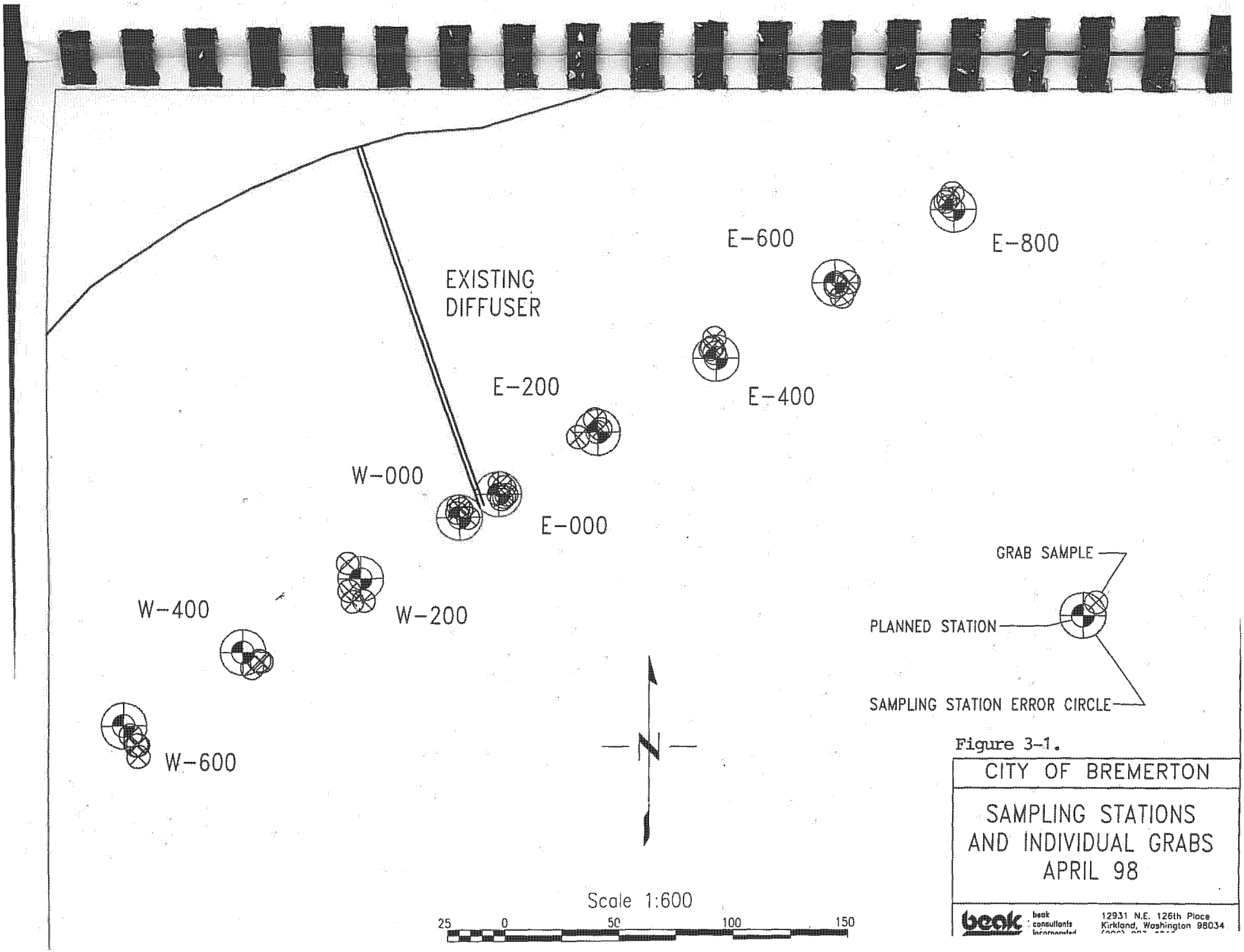

Figure 3-1.

CITY OF BREMERTON

SAMPLING STATIONS
AND INDIVIDUAL GRABS
APRIL 98

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The location of the center of each group of grab samples and the average water depth for each sample are reported in Table 3-1. The station centers are expressed in UTM coordinates to the nearest meter and in WGS84 (NAD 83) geodetic coordinate latitude and longitude to the nearest one-hundredth second.

Table 3-1. Actual Sampling Station Locations.

	UTM Coordinates Zone 10 (WGS84 - m)		Approximate Depth (feet) (MLLW)	Geodetic Coordinates WGS84 (NAD 83)	
Station Center	Northing	Easting	Feet	N. Latitude	W. Longitude
W-000	5265944.99	524843.28	29	47° 32' 47.22"	122° 40' 11.44"
W-200	5265911.88	524793.02	43	47° 32' 46.16"	122° 40' 13.85"
W-400	5265878.18	524754.51	46	47° 32' 45.07"	122° 40' 15.70"
W-600	5265841.25	524700.94	37	47° 32' 43.88"	122° 40' 18.27"
W-800	5265818.29	524643.07	20	47° 32' 43.15"	122° 40' 21.04"
E-000	5265951.02	524862.97	32	47° 32' 47.42"	122° 40' 10.49"
E-200	5265984.22	524901.72	32	47° 32' 48.49"	122° 40' 8.63"
E-400	5266014.75	524952.23	30	47° 32' 49.47"	122° 40' 6.21"
E-600	5266042.26	525007.43	26	47° 32' 50.35"	122° 40' 3.56"
E-800	5266080.65	525055.24	27	47° 32' 51.59"	122° 40' 1.27"

3.3 Sample Collection

Sediment sampling was conducted by Mr. Bob Suggs and Ms. Cathy McNair of Beak Consultants on 28 and 29 April 1998. The vessel employed for sediment sampling was a 26-foot work boat with an inboard diesel-powered jet drive. The vessel was equipped with a DGPS navigation system, a davit, winch, and all sampling equipment. The sampling vessel was launched from a public marina in Port Orchard in Sinclair Inlet, once all sampling equipment was operational.

Sample collection was conducted in accordance with the PSEP protocols as specified in the SAP. Samples were collected with a modified 0.1-square-meter van Veen sampler. The sample retained in the sampler was evaluated using acceptability criteria established in the PSEP protocols. Before sediment was removed from the sampler, the overlying water was removed by slowly pumping it off near one side of the sampler. Once the overlying water and any unrepresentative material were moved, sample observations were recorded on the field sample log.

Sample collection typically required one to two hours at each sampling station, during which time technicians obtained several grab samples, recorded field notes, preserved and labeled samples, decontaminated equipment, and re-positioned the sampling vessel. Approximately six liters of sediment were collected at each station for chemical and potential bioassay analyses. Stations E-000 through E-800 and Station W-000 were sampled on the first day of the field effort, with the remaining four Stations, W-200 through W-800, sampled on the second field day.

3.4 Sample Preparation and Logging

Prior to sampling at each station the sediment sampling equipment (van Veen sampler, stainless steel mixing bowls, and stainless steel spoons) was decontaminated using tri-sodium phosphate detergent and tap water, pesticide-grade acetone, and instrument-grade methyl alcohol as specified in the SAP. Utensils and bowls were then covered to prevent airborne or other contamination. All handling of equipment and samples was conducted with latex gloves, which were discarded after work was completed at each sampling station to prevent cross-contamination.

As samples were collected, logs and field notes of all sediment samples were maintained in the field log book and correlated to the sampling station identification. After completion of field observations, the top 2 cm of sediment was collected using a flat stainless steel spatula. Sediment in contact with the sides of the sampler was not collected. The collected sediments from all

acceptable grabs at each sampling station were placed in a clean, dry, stainless steel mixing bowl and homogenized with a clean stainless steel spatula. One sample from each sampling station was thoroughly homogenized and distributed among appropriate containers for chemical and bioassay analyses, and placed in a cooler with frozen blue ice and packing material. All samples were recorded on chain-of-custody forms. At the end of the first day, samples were packed in ice and sealed in coolers. Upon completion of sampling all samples were transported to the Beak office and placed in refrigerated storage.

3.5 Chemical Analyses

Samples were submitted to AmTest Inc. in Redmond, Washington for analysis of sediment conventionals and SMS contaminants of concern. The analyses results from testing for the 47 SMS chemicals of concern are considered the "initial designation" of sediments. The chemicals tested for fall into the following groups:

- Sediment Conventionals
- Grain Size
- Metals
- Polycyclic Aromatic Hydrocarbons
- Chlorinated Hydrocarbons
- Volatile Organic Compounds
- Organo-Nitrogen Compounds
- Phthalate Esters
- Phenols
- Polychlorinated Biphenyls (PCBs)
- Miscellaneous Organics

Detailed lists of all parameters, analytical methods and detection limits are included in the analytical laboratory report in Appendix A. The methods, holding times and QA/QC documentation reflect the analytical protocols described in the PSEP protocols (Puget Sound

Estuary Program 1986, 1989a, 1989b) and in EPA methods for solid waste and water quality analyses (U.S. Environmental Protection Agency 1982, 1988).

With the exception of mercury, the sediment samples were prepared for metals analysis using the strong acid digestion (SAD) method described in PSEP (1986). Following the acid and peroxide digestion, the subsequent solutions were analyzed in accordance with USEPA (1988). Arsenic, cadmium and silver were analyzed by graphite furnace atomic absorption (GFAA) method 7060 (U.S. Environmental Protection Agency, 1988). Copper, chromium, lead, and zinc were analyzed by inductively coupled plasma (ICP) emission spectroscopy method 6010 (Environmental Protection Agency, 1988). Mercury was digested and analyzed by cold vapor atomic absorption (CVAA) spectroscopy in accordance with method 7471 (U.S. Environmental Protection Agency, 1988).

To achieve detection limits below the SQS criteria for semi-volatile compounds, two separate 35 gram subsamples were extracted (EPA Method 3550 -sonication) and combined for a final extract volume of 1 ml. Gel Permeation Chromatography (GPC) cleanup (EPA Method 3640) was then performed on the final extract prior to instrumental analysis. Semivolatile organic analysis was completed on gas chromatograph/mass spectroscopy (GC/MS) instruments tuned and calibrated following EPA method 8270 requirements. Dual column confirmation was used for all samples.

Separate 35 gram subsamples were extracted (EPA 3540) and analyzed for the Polychlorinated Biphenyls (method 8081). the clean-up techniques documented in the respective analytical procedures (florisil, alumina etc.) were employed in order to reduce any matrix problems (final extract volume of 5 ml). Dual column confirmation was utilized in the samples where target compounds were detected.

In order to obtain limits of detection that were below the regulatory limits for SMS, Hexachlorobenzene was analyzed as a compound in the 8081 analysis (GC/ECD) as opposed to 8270 (GC/MS).

In spite of the relatively low total solids content of the samples (range 23-33%), there was a favorable relationship between the Method Detection Limit (MDL's) and the regulatory limits. Only one of the MDL's (2,4-Dimehylphenol, sample 98-A005915) exceeded any of the SMS regulatory limits. However, in that same sample, the levels of Mercury (0.953mg/Kg) and Bis(2-ethylhexyl)phthalate (57 ug/Kg) exceeded their respective "Chemical Criteria." There were no major problems with any of the analyses.

3.6 Bioassay Analyses

All ten test sediments collected were found to have chemical concentrations exceeding the marine SQS chemical criteria of WAC 173-204-310, and thus failed the "initial designation.", primarily due to the presence of high concentrations of mercury in all ten sediment samples. However, upon discussions between Mr. Gerald Erickson of Beak Consultants and Ms. Kathy Bragdon-Cook of Ecology, it was decided that only six of the ten sediments would be subjected to "Confirmatory Marine Sediment Biological Tests" (WAC 173-204-315). Bioassay tests were performed on sediment samples collected at Stations W-000, W-200, W-400, E-000, E-400 and E-800. This includes two samples immediately adjacent to the outfall (W-000 and W-200) with elevated concentrations of phthalate esters (which may be associated with the outfall) and four additional samples where only mercury was present in levels greater than the SQS criterion. These four additional samples were chosen (collected at Stations W-400, E-000, E-400 and E-800) to provide the City with data which may be useful in discussions regarding sediment cleanup efforts in Sinclair Inlet, and because they are in areas which had not previously been sampled extensively by the Navy and other agencies, as they lay outside current established clean-up sites.

This was determined by the use of Ecology maps depicting sediment cleanup sites in the Inlet. It is recognized by Ecology that mercury has been found to be widely present in contaminated sediments from Sinclair Inlet, with multiple potential sources besides the City's WWTP outfall.

If confirmatory testing is to be performed on sediment failing the initial designation, WAC 173-204-315 requires that two acute bioassays and one chronic bioassay be conducted (Washington State Department of Ecology, 1995). Thus, the bioassay testing on the six samples was conducted using the following tests/organisms:

- (Acute) 10-day Amphipod Mortality Bioassay (*Ampelisca abdita*)
- (Acute) 48-hour Echinoderm Larval Development Bioassay (*Dendraster excentricus*)
- (Chronic) 20-day Juvenile Polychaete Growth Rate Bioassay (*Neanthes arenaceodentata*)

Testing was conducted on a subsample of the same sample analyzed for sediment chemistry for each station. Because of the considerable time required to perform and evaluate the chemical analyses for the 10 sediment samples, the eight-week holding time specified in the amended SMS was used for this study. Prior to test initiation, all bioassay sediment samples were stored in the dark at 4°C; each sample container headspace was purged with nitrogen prior to being stored. Chain-of-custody procedures were maintained by the laboratory throughout the biological testing.

All bioassays were conducted in accordance with the most current version of the PSEP bioassay protocols (Puget Sound Estuary Program, 1995). *Ampelisca abdita* was chosen instead of *Rhepoxinius abronius* for the amphipod test due to it's better tolerance of the high percentages of fine sediment present in these samples. Each bioassay analysis was conducted with concurrent positive controls, negative controls, and reference sediment that were prepared and tested under identical conditions as the test sediment. The controls ensure that the bioassays met the SMS performance standards required by WAC 173-204-315.

Positive controls are non-sediment controls conducted with a known toxicant to ensure that the sensitivity of the test organisms is normal. A cadmium chloride dilution series was used as the positive control toxicant for all three bioassays.

Negative controls are clean, native sediments used to monitor the effects of collection and handling of the organisms, in addition to monitoring laboratory performance. The negative control sediment was collected from West Beach, Whidbey Island, Washington for both the Amphipod and Juvenile Polychaete Bioassays. The Echinoderm Larval Sediment Bioassay utilizes a negative seawater control rather than a control sediment. The seawater control was sterilized using UV-treatment and filtered using a 0.45 μm filter.

Reference sediments are "clean" native sediments which have similar grain-size characteristics to those of the test sediments (e.g., within $\pm$ 5% fines). The reference sediment is used as a control for the physical characteristics/effects of the test sediment and as a basis for comparison and interpretation of the test sediment results. The reference sediment used for these bioassays was collected from Carr Inlet, west of Tacoma, Washington.

Each bioassay was conducted with six replicates of each of the test, reference, and negative control sediments, and two replicates of the positive control concentrations. Five of the replicates were used for measuring the bioassay endpoint (e.g., survivorship or normality), and one replicate was used solely for monitoring water quality. Water quality parameters were measured at specific intervals to ensure that they were within the PSEP quality assurance parameters. Dissolved oxygen, temperature, pH, and salinity, were monitored daily for the Amphipod and Echinoderm Larval Sediment Bioassay and every three days for the Juvenile Polychaete Sediment Bioassay. Total ammonia and total sulfides in the overlying water were determined in the water quality replicate at test initiation and termination for each bioassay.

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3.7 Sediment Chemistry and Bioassay Interpretation Criteria

The results of the chemical and biological analyses were compared with the SMS numerical criteria for marine sediments. The SMS chemical criteria are based on a biological effects-based approach that uses the apparent effects threshold (AET) values for four biological indicators in the marine environment. Under SMS, numerical chemical criteria and biological effects criteria are established at two levels:

- Sediment Quality Standards (SQS) - marine chemical and biological effects criteria (lower level)

- Sediment Impact Zones maximum (SIZ_{max}) - marine chemical and biological criteria (higher level).

The chemical criteria have been developed for 47 chemicals. Biological effects criteria have been established for benthic abundance, two acute and two chronic bioassays. Sediment impact zone maximum criteria are based on a range of allowable levels of contamination that is applied on a site-specific basis. The low end of the range is the SQS; the upper end of the range is defined by the SIZ_{max}. The SIZ_{max} numerical criteria are identical to the SMS Cleanup Screening Level (CSL) and Minimum Cleanup Level (MCUL) criteria, but each of the three is used for different regulatory purposes. As indicated by the titles, the SIZ_{max} is used for identified sediment impact zones (typically near outfalls), the CSL criteria are used to determine if clean-up is necessary at a given site, and the MCUL is used as a minimum clean-up standard for a site where cleanup has been deemed necessary. Table 3-2 presents the SQS and SIZ_{max} chemical criteria. Table 3-3 presents the bioassay criteria and performance standards.

Table 3-2. Sediment Quality Standards and Impact Zones Maximum Chemical Criteria

Chemical Parameter	Sediment Quality Standards Chemical Criteria(SQS)[1]	Impact Zones Maximum Chemical Criteria (SIZ_{max})[1]
METALS	**mg/kg Dry Weight**	**mg/kg Dry Weight**
Arsenic	57	93
Cadmium	5.1	6.7
Chromium	260	270
Copper	390	390
Lead	450	530
Mercury	0.41	0.59
Silver	6.1	6.1
Zinc	410	960
Organic Compounds	**mg/kg Organic Carbon[2]**	**mg/kg Organic Carbon[2]**
LPAH[3]	370	780
Naphthalene	99	170
Acenaphthylene	66	66
Acenaphthene	16	57
Fluorene	23	79
Phenanthrene	100	480
Anthracene	220	1,200
2-Methylnaphthalene	38	64
HPAH[4]	960	5,300
Fluoranthene	160	1,200
Pyrene	1,000	1,400
Benzo(a)anthracene	110	270
Chrysene	110	460
Total benzofluoranthenes[5]	230	450
Benzo(a)pyrene	99	210
Indeno(1,2,3-C,D)pyrene	34	88
Dibenzo(a,h)anthracene	12	33
Benzo(g,h,i)perylene	31	78
1,2-Dichlorobenzene	2.3	2.3
1,4-Dichlorobenzene	3.1	9
1,2,4-Trichlorobenzene	0.81	1.8

Table 3-2. Sediment Quality Standards and Impact Zones Maximum Chemical Criteria

Chemical Parameter	Sediment Quality Standards Chemical Criteria(SQS)[1]	Impact Zones Maximum Chemical Criteria (SIZ_{max})[1]
Organic Compounds (cont'd)	**mg/kg Organic Carbon[2]**	**mg/kg Organic Carbon[2]**
Hexachlorobenzene	0.38	2.3
Dimethyl phthalate	53	53
Diethyl phthalate	61	110
Di-n-butyl phthalate	220	1,700
Butyl benzyl phthalate	4.9	64
Bis(2-ethylhexyl)phthalate	47	78
Di-n-octyl phthalate	58	4,500
Dibenzofuran	15	58
Hexachlorobutadiene	3.9	6.2
N-nitrosodiphenylamine	11	11
Total PCBs	12	65
MISC. EXTRACTABLE COMPOUNDS	**µg/kg Dry Weight**	**µg/kg Dry Weight**
Phenol	420	1,200
2-Methylphenol	63	63
4-Methylphenol	670	670
2,4-Dimethyl phenol	29	29
Pentachlorophenol	360	690
Benzyl alcohol	57	73
Benzoic acid	650	650

1 - Where laboratory indicates a chemical is not detected in a sediment sample, the detection limit shall be reported and shall be at or below the criteria value shown in this table. Where chemical criteria in this table represent the sum of individual compounds or isomers, the following methods shall be applied: (a) Where chemical analyses identify an undetected value for every individual compounds or isomers, then the single highest detection limit shall represent the sum of the respective compounds or isomers; and (b) Where chemical analyses detected one or more individual compounds or isomers, only the detected concentrations will be added to represent the group sum.

2 - The listed chemical parameter criteria represent concentrations in parts per million "normalized," or expressed, on a total organic carbon basis. To normalize to total organic carbon, the dry weight concentration for each parameter is divided by the decimal fraction representing the percent total organic carbon content of the sediment.

3 - The LPAH criterion represents the sum of the following "low molecular weight polynuclear aromatic hydrocarbon" compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. The LPAH criterion is not the sum of the criteria values for the individual LPAH compounds as listed.

4 - The HPAH criterion represents the sum of the following "high molecular weight polynuclear aromatic hydrocarbon" compounds: fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. The HPAH criterion is not the sum of the criteria values for the individual HPAH compounds as listed.

5 - The total benzofluoranthenes criterion represents the sum of the concentrations of the "B," "J," and "K" isomers.

Table 3-3. Sediment Quality Standards and Impact Zones Maximum Biological Effects Criteria.

	Sediment Management Standards Criteria		Bioassay Performance Standards		
Bioassay Analysis	SQS[1]	SIZ_{max}[1]	Reference Sediment	Negative Control	Positive Control [2]
Amphipod	1) statistically different t-test ($p \leq 0.05$) 2) test sediment mean mortality is 25% greater than reference sediment mean mortality	1) statistically different t-test ($p \leq 0.05$) 2) test sediment mean mortality is 30% greater than reference sediment mean mortality	less than 25% mortality	less than 10% mortality	96 hr LC_{50} for Cd concentration of 0.31 to 1.27 mg/l [2]
Larval (Echinoderm)	1) statistically different t-test ($p \leq 0.05$) 2) test sediment has a mean combined abnormality and mortality 15% greater than the mean combined abnormality and mortality of the reference sediment	1) statistically different t-test ($p \leq 0.05$) 2) test sediment has a mean combined abnormality and mortality 30% greater than the mean combined abnormality and mortality of the reference sediment	normal survivorship at least 65% of negative control normal survivorship [2]	less than 30% combined mortality and abnormality (>70% normal survivorship)	96 hr LC_{50} for Cd concentration of 3.6 to 16.6 mg/l [2]
Juvenile Polychaete	1) statistically different t-test ($p \leq 0.05$) 2) test sediment has a mean individual growth rate less than 70% of the reference sediment mean individual growth rate	1) statistically different t-test ($p \leq 0.05$) 2) test sediment has a mean individual growth rate less than 50% of the reference sediment mean individual growth rate	mean individual growth rate at least 80% of negative control growth rate	less than 10% mortality and greater than 0.72mg/ind/day growth rate	96 hr LC_{50} for Cd concentration of 7.1 to 17.9 mg/l [2]

1- The sediment impact zone maximum biological effects level is established as that level below which any two of the biological tests in combination exceed the SQS criteria or any one of the biological tests exceeds the SIZ_{max} criteria.

2- Performance standard established by bioassay protocol, not specified in WAC 173-204-315.

4.0 RESULTS AND DISCUSSION

4.1 Sediment Sampling Observations

Sediments sampled from the area east of the WWTP outfall diffuser consisted of green-black (E-000) to olive green (E-200 to E-800) colored silt. Sediments sampled closest to the outfall (E-000) had a slight hydrogen sulfide odor. Sediments sampled from the area west of the WWTP outfall consisted of black (W-000), green (W-400), and green-grey (W-200, W-600 and W-800) silt. Sediments collected at Stations W-000 (closest to the outfall) and W-400 had a slight hydrogen sulfide odor, with Station W-200 sediments having a stronger hydrogen sulfide odor. Sediment sampled from Station W-000 was found to contain band-aids and plastic material.

4.2 Chemical Analyses Results

4.2.1 Conventional parameters

The full analytical laboratory report from AMTEST is found in Appendix A, including QA/QC information. Conventional sediment analyses were conducted in accordance with PSEP protocols (Puget Sound Estuary Program, 1986). All of the results are reported on a dry weight basis. The grain-size analysis was performed using Tyler screens and hydrometer techniques. Tables 4-1 (for Stations west of the WWTP outfall) and 4-2 (Stations east of the outfall) present the conventional analyses data for the 10 test sediments. Results of the sediment grain size analysis are presented in Tables 4-3 (Stations west of the outfall) and 4-4 (Stations east of the outfall); the relative distribution of grain size determined from these analyses is depicted graphically in Figures 4-1 and 4-2 respectively.

Table 4-1. Dry-weight concentration data summary for sediment conventionals and metals Stations west of the City of Bremerton WWTP outfall							
Sampling Station ID. Laboratory Sample ID.	W-000 98-00A5915	W-200 98-A005916	W-400 98-A005917	W-600 98-A005918	W-800 98-A005919	SQS	MCL
CONVENTIONALS							
Ammonia (mg/kg)	15	20	22	27	25		
Total Oil and Grease (mg/kg)	1500	670	510	640	690		
Total Solids (%)	32.1	27.6	24.8	24.3	22.9		
Total Volatile Solids (%)	15	11	11	10	11		
Total Organic Carbon (%)	4.70	3.60	3.20	3.50	3.80		
Total Sulfides (mg/kg)	200	950	1100	1500	1100		
METALS (mg/kg (ppm) dry weight)							
Arsenic	12	12	11	11	10	57	93
Cadmium	1.5	0.9	0.9	1.1	1.1	5.1	6.7
Chromium	83	60	75	69	73	260	270
Copper	180	180	190	170	180	390	390
Lead	140	110	120	110	110	450	530
Mercury	0.953	0.866	0.96	0.889	0.843	0.41	0.59
Silver	3.1	<0.1	1.6	1.2	1.3	6.1	6.1
Zinc	300	210	250	220	240	410	960

U - Indicates the compound was analyzed for but not detected at the given detection limit.
Y - Indicates a raised detection limit due to matrix interferences. Compound was not detected.
D - Indicates an initial value above the linear range of the detector. Sample diluted before analysis.

Table 4-2. Dry-weight concentration data summary for sediment conventionals and metals Stations east of the City of Bremerton WWTP outfall

Sampling Station ID.	E-000	E-200	E-400	E-600	E-800	SQS	MCL
Laboratory Sample ID.	98-00A5920	98-A005921	98-A005922	98-A005923	98-A005924		
CONVENTIONALS							
Ammonia (mg/kg)	22	18	18	13	16		
Total Oil and Grease (mg/kg)	560	450	460	340	400		
Total Solids (%)	27.5	27.5	30.2	31.5	33.4		
Total Volatile Solids (%)	11	9.6	8.9	8.3	9		
Total Organic Carbon (%)	3.60	3.40	3.10	2.90	2.90		
Total Sulfides (mg/kg)	770	530	65	25	41		
METALS (mg/kg (ppm) dry weight)							
Arsenic	12	12	11	10	<0.6	57	93
Cadmium	0.9	0.9	0.8	0.7	0.69	5.1	6.7
Chromium	57	68	69	55	59	260	270
Copper	140	160	170	150	170	390	390
Lead	77	96	110	97	120	450	530
Mercury	0.89	0.86	0.88	0.83	0.829	0.41	0.59
Silver	1.5	1.6	1.5	1.1	1.2	6.1	6.1
Zinc	180	260	220	190	260	410	960

U - Indicates the compound was analyzed for but not detected at the given detection limit.
Y - Indicates a raised detection limit due to matrix interferences. Compound was not detected.
D - Indicates an initial value above the linear range of the detector. Sample diluted before analysis.

TABLE4-3. Sediment grain size summary.
Stations west of the City of Bremerton WWTP outfall.

WENTWORTH CLASSIFICATION	Grain Size Phi	Grain Size Microns	98-A005915 W-000	98-A005916 W-200	98-A005917 W-400	98-A005918 W-600	98-A005919 W-800
GRAVEL		>4750	3.4	0.1	0.1	0.1	0.1
GRAVEL	-2 to -1	4750-2000	2.8	0.5	0.2	0.5	0.2
SAND	0	2000-1000	3.4	0.4	0.4	0.1	0.4
SAND	+1	1000-500	3.1	0.7	0.4	0.4	0.4
SAND	+2	500-250	6.2	2.5	1.2	2.1	0.4
SAND	+3	250-125	5.0	2.9	1.6	2.9	2.2
SAND	+4	125-62.5	5.3	4.7	3.2	3.3	3.9
SILT	+5	62.5-31.2	11.4	19.3	11.4	16.0	12.0
SILT	+6	31.2-15.6	11.5	15.9	15.4	13.1	19.5
SILT	+7	15.6-7.8	13.3	17.8	23.7	19.3	19.5
SILT	+8	7.8-3.9	13.8	13.5	17.8	19.3	19.5
CLAY	+9	3.9-1.9	6.4	5.8	6.9	5.5	6.6
CLAY	+10	1.9-0.9	3.1	2.7	3.0	2.1	3.3
CLAY	>+10	<0.9	11.2	13.4	14.9	15.6	16.2
% GRAVEL			6%	1%	0%	1%	0%
%SAND			24%	11%	7%	9%	8%
% SILT			52%	66%	68%	68%	73%
%CLAY			21%	22%	25%	23%	27%
% FINES			71%	88%	93%	91%	93%

TABLE4-4. Sediment grain size summary.
Stations east of the City of Bremerton WWTP outfall.

WENTWORTH CLASSIFICATION	Grain Size Phi	Grain Size Microns	98-A005920 E-000	98-A005921 E-200	98-A005922 E-400	98-A005923 E-600	98-A005934 E-800
GRAVEL		>4750	0.1	0.4	0.1	0.1	4.5
GRAVEL	-2 to -1	4750-2000	1.4	0.2	0.6	0.6	0.9
SAND	0	2000-1000	1.5	0.4	0.3	0.6	0.3
SAND	+1	1000-500	1.5	0.7	0.7	0.6	0.6
SAND	+2	500-250	4.7	1.8	1.3	1.6	3.0
SAND	+3	250-125	4.0	1.8	2.0	2.5	2.7
SAND	+4	125-62.5	4.7	5.1	6.3	7.3	7.5
SILT	+5	62.5-31.2	11.1	14.6	13.8	17.3	18.3
SILT	+6	31.2-15.6	16.3	16.0	19.8	14.4	12.7
SILT	+7	15.6-7.8	18.0	21.5	16.3	17.3	16.2
SILT	+8	7.8-3.9	15.0	16.0	12.2	15.6	11.7
CLAY	+9	3.9-1.9	5.5	5.5	5.1	3.6	4.2
CLAY	+10	1.9-0.9	2.7	2.7	2.5	0.8	1.5
CLAY	>+10	<0.9	13.5	13.5	18.9	17.2	15.9
% GRAVEL			2%	1%	1%	1%	5%
%SAND			16%	10%	11%	13%	14%
% SILT			60%	68%	62%	65%	59%
%CLAY			22%	22%	27%	22%	22%
% FINES			82%	90%	89%	87%	81%

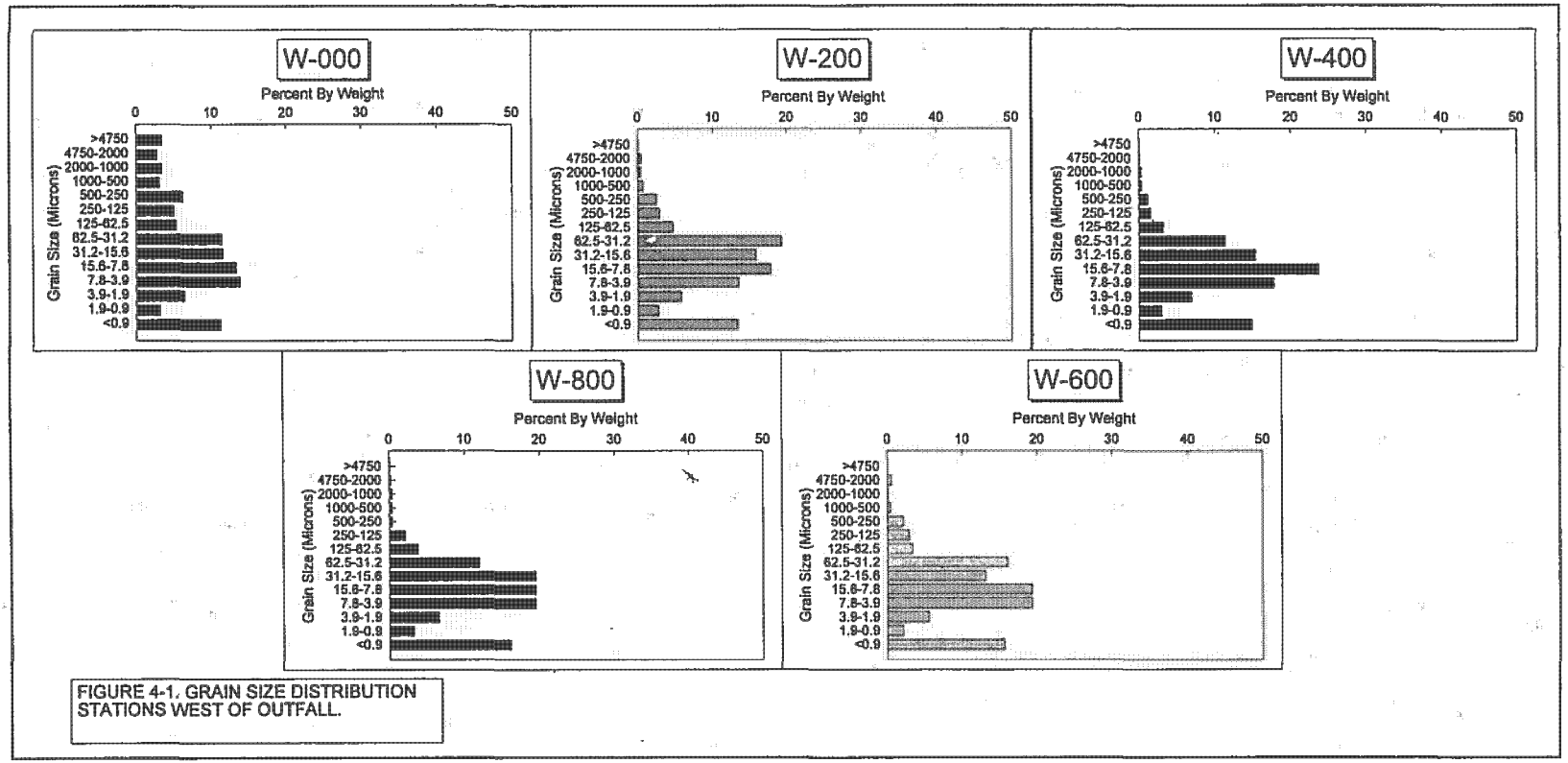

FIGURE 4-1. GRAIN SIZE DISTRIBUTION STATIONS WEST OF OUTFALL.

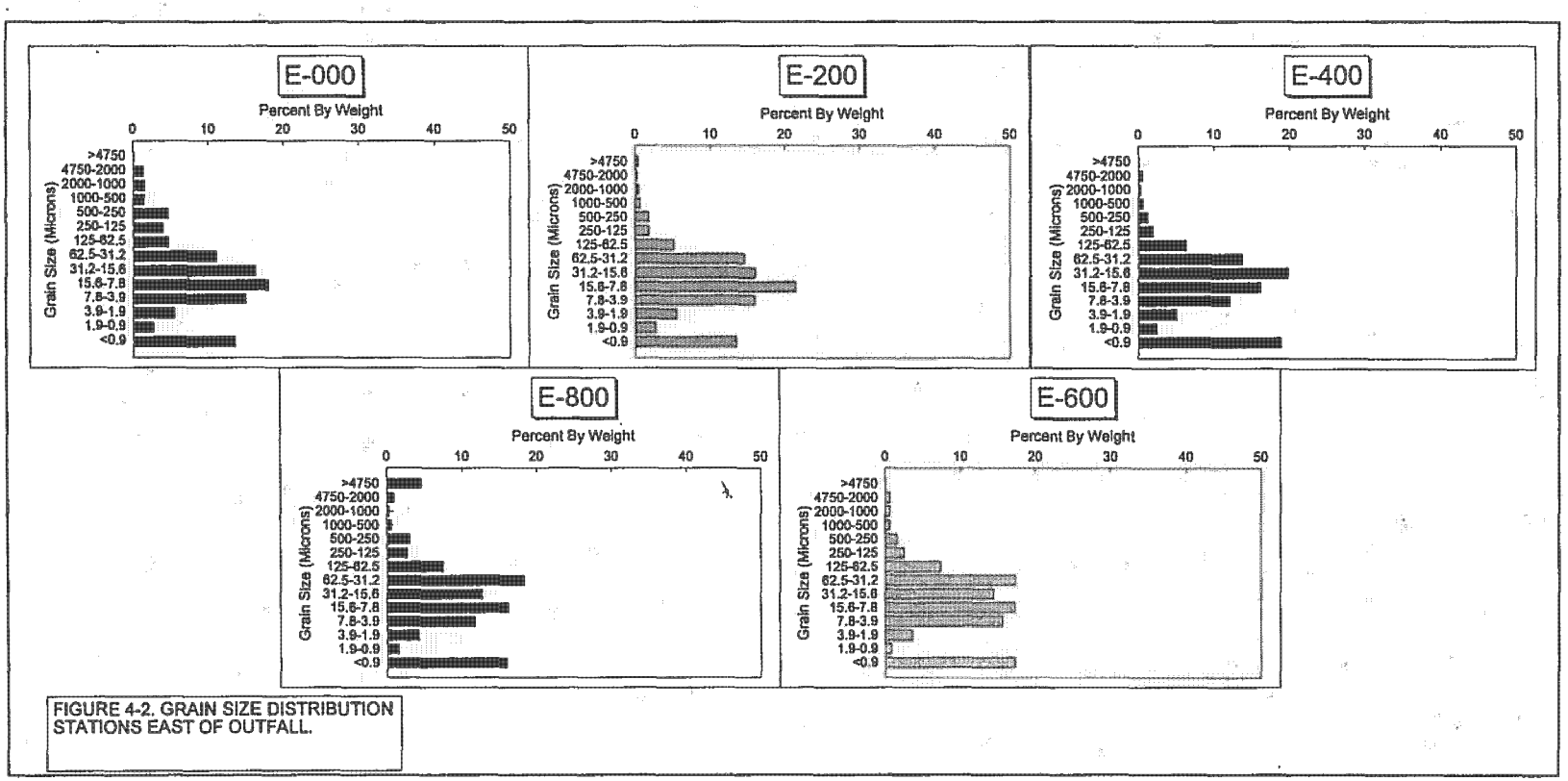

FIGURE 4-2. GRAIN SIZE DISTRIBUTION STATIONS EAST OF OUTFALL.

Sediment samples from Stations located west of the WWTP outfall had relatively high concentrations of conventional parameters. Oil and grease (O&G) concentrations ranged from 510 to 1500 mg/kg, total volatile solids (TVS) ranged from 10 to 15 percent, total organic carbon (TOC) ranged from 3.20 to 4.70 percent, ammonia ranged from 15 to 27 mg/kg, and sulfides ranged from 200 to 1500 mg/kg. Concentrations of O&G, TVS and TOC were highest at Station W-000, the station closest to the outfall. In contrast, total sulfides and ammonia concentrations were lowest at Station W-000, and highest at Station W-600.

Sediment samples from Stations located east of the WWTP outfall also had relatively high concentrations of conventional parameters, but at lower levels than those seen at the Stations west of the outfall. Oil and grease (O&G) concentrations ranged from 340 to 560 mg/kg, total volatile solids (TVS) ranged from 8.3 to 11 percent, total organic carbon (TOC) ranged from 2.90 to 3.60 percent, ammonia ranged from 13 to 22 mg/kg, and sulfides ranged from 25 to 770 mg/kg. Concentrations of ammonia, O&G, TVS, TOC and sulfides were all highest at Station E-000, the station closest to the outfall.

Sediments collected from both the west and the east of the outfall were found to be predominately silty material in the 3.9 to 62.5 μ range (Tables 4-3 and 4-4). Sediments collected west of the outfall ranged from 52% to 73% silt, and sediments collected east of the outfall ranged from 59% to 68% silt. The samples had high percent fines (silts + clays) ranging from 71% to 93% in samples collected at Stations to the west of the outfall, and from 81% to 90% in sediments collected at Stations to the east of the outfall. This was also true for sediments collected in the vicinity for the Puget Sound Navy Shipyard discussed above (URS Consultants, 1994).

The fact that the sediment samples collected have predominately finer grain size material is associated with the correspondingly higher concentrations of TOC, TVS, ammonia and sulfides in the samples. Sediments collected from some of the Stations are likely to be somewhat anoxic

as well, as evidenced by the high ammonia and sulfide concentrations, and the corresponding hydrogen sulfide odor noted above. Although most of the conventional parameters are highest at Stations closest to the outfall, high levels also occur in more distant Stations, which indicates that other sources of organic loading are likely present as well.

4.2.2 Metals

Tables 4-1 and 4-2 present the results of the metals analyses compared with the SMS marine sediment chemical criteria. Of the eight metals analyzed, none exceeded the SQS or SIZ_{max} criteria in any of the test samples, with the exception of mercury which was found to exceed the SIZ_{max} criterion in sediments collected from every Station sampled. Mercury concentrations ranged from 0.843 to 0.96 mg/kg dry weight in sediments collected from Stations west of the WWTP outfall, and ranged from 0.829 to 0.89 mg/kg in sediments collected from Stations east of the WWTP outfall. The concentration levels are relatively similar, making detection of any significant trends in the data difficult. However, there appears to be a slight trend in that the highest or next to the highest concentrations are found in Stations W-000 and E-000 closest to the outfall, and the lowest concentrations are found at the Stations furthest away, W-800 and E-800.

As noted above in Section 2.2, mercury contamination has been found to be a widespread problem in all of Sinclair Inlet, and is not restricted to the area in the vicinity of the outfall, although mercury has been detected in the Bremerton WWTP effluent in the past. The mercury concentrations found in sediments collected in this current study are similar to those found in the Puget Sound Naval Shipyard study cited above (URS Consultants, 1994). In that study, the four stations closest to the City of Bremerton WWTP outfall had mercury concentrations ranging from 0.86 to 1.20 mg/kg. Mercury concentrations in sediments collected at other Stations in the vicinity of the Shipyard ranged from 0.01 to 4.20 mg/kg, with mercury detected at levels exceeding the SQS criterion in 34 out of a total of 38 Stations sampled. In addition, marine

sediment monitoring data collected at Station 34 in Sinclair Inlet by Ecology (Figure 2-1), indicates that mercury is present at high levels (Table 4-5) in an area away from the WWTP outfall. In chemical analyses conducted on sediment samples collected from 1989 to 1995 at this station, concentrations ranged from 0.43 to 0.86 mg/kg. Thus, all of the available evidence points toward the conclusion that mercury contamination is an area-wide problem in Sinclair Inlet.

4.2.3 SMS Organic Compounds

Tables 4-6 and 4-7 present the organic analyses results for the 39 SMS organic compounds analyzed in the WWTP outfall samples, with all non-polar compound concentrations normalized for TOC as specified in the SMS. The SMS criteria for these compounds have also been presented in the tables for comparison with the test sediment concentrations. All sediment concentrations that exceed the SQS criteria have been shaded with gray. All concentrations that exceed the SIZ_{max} criteria have been printed in reverse text and shaded with black.

A majority of the compounds tested for were not detected in the WWTP outfall samples, and of those that were detected most had very low concentrations relative to the SQS criteria. Only two samples had measured concentrations of organic compounds which exceeded either the SQS or SIZ_{max} criteria, when normalized for TOC.

One sample (W-000) was found to have a measured concentration of 57 mg/kg (organic carbon) of bis(2-ethylhexyl)phthalate which exceeded the TOC-normalized SQS criterion but was below the SIZ_{max} criterion. This was the only organic compound found above detection limits in the sample. An additional sample (W-200) had a measured concentration of 5.6 mg/kg (organic carbon) of Butylbenzylphthalate which also exceeded the TOC-normalized SQS criterion (but below the SIZ_{max} criterion). This was also the only organic compound found above detection limits in this sample.

Table 4-5 Selected Washington State Department of Ecology Marine Sediment Monitoring data for Station 34 - Sinclair Inlet (47° 32.825'N; 122° 39.725'W), compared to data from current study.

Dry weight concentrations (not normalized to organic carbon)			
Year	Mercury (ppm)	Bis(2-ethylhexyl) phthalate (ppb)	Butylbenzyl phthalate (ppb)
1989	0.86	160.0	31.0
1990	0.87	560.0	21.0
1991	0.74	140.0	28.0
1992	0.58	94.0	38.0
1993	0.43	230.0	35.73
1994	0.79	--	--
1995	0.62	--	--
Station	Mercury (ppm)	Bis(2-ethylhexyl) phthalate (ppb)	Butylbenzyl phthalate (ppb)
W-000	0.953	2700	Undetected
W-200	0.866	540	200
W400-W800	0.843 to 0.96	260-640	Undetected
E000-E800	0.829-0.89	190-940	Undetected; E200=55
Criteria	SQS = 0.41	LAET = 1300	LAET = 63
Criteria	SIZ_{max} = 0.59	HAET = >3100	HAET = 200

Station 34 is approximately 625 yards (1875 ft.) ENE of outfall diffuser (Figure 2-1).

LAET = Lowest Apparent Effects Threshold

HAET = Highest Apparent Effects Threshold

Table 4-6. Sediment Management Standards data summary for organic compounds
Stations west of the City of Bremerton WWTP outfall

Sampling Station ID.	W-000	W-200	W-400	W-600	W-800	SQS	SIZ MAX
Laboratory Sample ID.	98-A005915	98-A005916	98-A005917	98-A005918	98-A005919		
ORGANICS PPM (MG/KG OC)							
LPAH'S							
Total LPAHs*	6.0	2.4	1.8 U	1.6	2.3	370	780
Naphthalene	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	99	170
Acenaphthylene	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	66	66
Acenaphthene	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	16	57
Fluorene	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	23	79
Phenanthrene	3.0	2.4	1.8 U	1.6	2.3	100	480
Anthracene	3	1.4 U	1.8 U	1.6 U	1.6 U	220	1200
2-Methylnaphthalene	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	38	64
HPAH'S							
Total HPAHs*	25.5	31.5	18.9	23.9	29.4	960	5300
Fluoranthene	5.3	4.4	3.4	4.0	5.3	160	1200
Pyrene	11.0	5.8	3.8	4.9	6.6	1000	1400
Benzo(a)anthracene	1.8 U	2.8	1.9	2.1	2.6	110	270
Chrysene	1.8 U	3.9	2.6	2.7	3.9	110	460
Total Benzofluoranthenes*	5.8	7.2	4.9	5.7	7.6	230	450
Benzo(b)fluoranthene	3.2	3.9	2.7	2.9	3.9		
Benzo(k)fluoranthene	2.6	3.3	2.2	2.8	3.7		
Benzo(a)pyrene	3.4	3.3	2.3	2.6	3.4	99	210
Indeno(1,2,3-cd)pyrene	1.8 U	2.1	1.8 U	1.6 U	1.6 U	34	88
Dibenzo(a,h)anthracene	1.8 U	1.5 U	1.8 U	1.6 U	1.6 U	12	33
Benzo(g, h, i)perylene	1.8 U	2.0	1.8 U	1.9	1.6 U	31	78
CHLORINATED BENZENES							
1,2,4-Trichlorobenzene	0.55 U	0.42 U	0.53 U	0.29 U	0.26 U	0.81	1.8
Hexachlorobenzene	0.091 U	0.14 U	0.18 U	0.29 U	0.26 U	0.38	2.3
1,2-Dichlorobenzene	0.15 U	0.25 U	0.31 U	0.49 U	0.47 U	2.3	2.3
1,4-Dichlorobenzene	0.15 U	0.25 U	0.31 U	0.16 U	0.16 U	3.1	9
PHTHALATES ESTERS							
Dimethylphthalate	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	53	53
Diethylphthalate	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	61	110
Di-n-Butylphthalate	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	220	1700
Butylbenzylphthalate	1.8 U	5.6	1.8 U	1.6 U	1.6 U	4.9	64
Bis(2-Ethylhexyl)phthalate	57	15	8.1	10	17	47	78
Di-N-Octyl phthalate	1.8 U	1.4 U	1.8 U	1.6 U	1.6 U	58	4500
MISCELLANEOUS							
Dibenzofuran	1.8	1.4 U	1.8 U	1.6 U	1.6 U	15	58
Hexachlorobutadiene	1.1	0.83 U	1.1 U	0.97 U	0.97 U	3.9	6.2
N-Nitrosodiphenylamine	0.91	0.69 U	0.91 U	0.83 U	0.79 U	11	11
PHENOLS & MISC. (UG/KG DRY WEIGHT)							
Phenol	85 U	51 U	58 U	57 U	61 U	420	1200
2 Methylphenol	43 U	25 U	29 U	29 U	30 U	63	63
4 Methylphenol	85 U	51 U	58 U	57 U	61 U	670	670
2,4-Dimethylphenol	**43 U	25 U	29 U	29 U	29 U	29	29
Pentachlorophenol	340 U	200 U	230 U	230 U	240 U	360	690
Benzyl alcohol	51 U	30 U	35 U	34 U	37 U	57	73
Benzoic acid	430 U	250 U	290 U	290 U	300 U	650	650
PCB's							
Total PCB's*	11.0	3.9	4.1	5.4	4.7	12	
Arochlor 1016	0.91	0.69 U	0.91 U	0.83 U	0.82 U		
Arochlor 1221	3.6	2.8 U	3.6 U	3.3 U	3.2 U		
Arochlor 1232	0.91	0.69 U	0.91 U	0.83 U	0.82 U		
Arochlor 1242	1.9	0.69 U	0.91 U	0.83 U	0.82 U		
Arochlor 1248	0.91	0.69 U	0.91 U	0.83 U	0.82 U		
Arochlor 1254	0.91	0.69 U	0.91 U	0.83 U	0.82 U		
Arochlor 1260	9.4	3.9	4.1	5.4	4.7		

* - Where chemical analyses identified an undetected value for every individual compound/isomer then the single highest detection limit represents the group sum; and where one or more inidividual compounds/isomers are detected, only the detected concentrations were added to represent the group sum.

** - Indicates that detection limit value is greater than SQS criteria. Refer to M. Fugiel explanation in Amtest report.

U - Indicates the compound was analyzed for but not detected at the given detection limit.

Table 4-7. Sediment Management Standards data summary for organic compounds
Stations east of the City of Bremerton WWTP outfall

Sampling Station ID.	E-000	E-200	E-400	E-600	E-800	SQS	SIZ MAX
Laboratory Sample ID.	98-A005920	98-A005921	98-A005922	98-A005923	98-A005924		
ORGANICS PPM (MG/KG OC)							
LPAH'S							
Total LPAHs*	3.3	1.5 U	4.6	2.6	2.6	370	780
Naphthalene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	99	170
Acenaphthylene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	66	66
Acenaphthene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	16	57
Fluorene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	23	79
Phenanthrene	3.3	1.5 U	2.3	2.6	2.6	100	480
Anthracene	1.4 U	1.5 U	2.3	1.5 U	1.4 U	220	1200
2-Methylnaphthalene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	38	64
HPAH'S							
Total HPAHs*						960	5300
Fluoranthene	5.3	2.2	4.8	5.9	6.2	160	1200
Pyrene	7.8	2.6	6.8	7.6	7.9	1000	1400
Benzo(a)anthracene	3.1	1.5 U	2.6	3.2	3.4	110	270
Chrysene	4.2	1.5 U	3.9	4.5	4.8	110	460
Total Benzofluoranthenes*						230	450
Benzo(b)fluoranthene	4.7	1.5 U	3.2	3.8	3.8		
Benzo(k)fluoranthene	3.1	1.5 U	3.2	3.4	3.3		
Benzo(a)pyrene	3.3	1.5	3.9	4.5	4.5	99	210
Indeno(1,2,3-cd)pyrene	1.4 U	1.5 U	1.5 U	2.4	1.4 U	34	88
Dibenzo(a,h)anthracene	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	12	33
Benzo(g, h, i)perylene	1.4 U	1.5 U	1.5 U	1.5 U	3.1	31	78
CHLORINATED BENZENES							
1,2,4-Trichlorobenzene	0.42 U	0.44 U	0.45 U	0.45 U	0.45 U	0.81	1.8
Hexachlorobenzene	0.14 U	0.15 U	0.15 U	0.16 U	0.14 U	0.38	2.3
1,2-Dichlorobenzene	0.25 U	0.26 U	0.26 U	0.28 U	0.28 U	2.3	2.3
1,4-Dichlorobenzene	0.25 U	0.26 U	0.26 U	0.28 U	0.28 U	3.1	9
PHTHALATES ESTERS							
Dimethylphthalate	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	53	53
Diethylphthalate	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	61	110
Di-n-Butylphthalate	3.1	1.5 U	1.5 U	1.5 U	1.4 U	220	1700
Butylbenzylphthalate	1.4 U	1.6	1.5 U	1.5 U	1.4 U	4.9	64
Bis(2-Ethylhexyl)phthalate	26	6.8	7.7	6.6	8.6	47	78
Di-N-Octyl phthalate	1.4 U	1.5 U	1.5 U	1.5 U	1.4 U	58	4500
MISCELLANEOUS							
Dibenzofuran	1.4	1.5 U	1.5 U	1.5 U	1.4 U	15	58
Hexachlorobutadiene	C 86	0.88 U	0.9 U	0.93 U	0.86 U	3.9	6.2
N-Nitrosodiphenylamine	0.72	0.74 U	0.74 U	0.76 U	0.72 U	11	11
PHENOLS & MISC. (UG/KG DRY WEIGHT)							
Phenol	51 U	51 U	46 U	44 U	42 U	420	1200
2 Methylphenol	26 U	25 U	23 U	22 U	21 U	63	63
4 Methylphenol	51 U	51 U	46 U	44 U	42 U	670	670
2,4-Dimethylphenol	26 U	25 U	23 U	22 U	21 U	29	29
Pentachlorophenol	200 U	200 U	180 U	180 U	170 U	360	690
Benzyl alcohol	31 U	30 U	28 U	27 U	25 U	57	73
Benzoic acid	260 U	250 U	230 U	220 U	210 U	650	650
PCB's							
Total PCB's*	5.4	4.6	5.8	4.5	4.0	12	
Arochlor 1016	0.81 U	0.74 U	0.74 U	0.76 U	0.72 U		
Arochlor 1221	2.8 U	2.9 U	3 U	3.1 U	2.90 U		
Arochlor 1232	0.72 U	0.74 U	0.74 U	0.76 U	0.72 U		
Arochlor 1242	0.72 U	0.74 U	0.74 U	0.76 U	0.72 U		
Arochlor 1248	0.72 U	0.74 U	0.74 U	0.76 U	0.72 U		
Arochlor 1254	0.72 U	0.74 U	0.74 U	0.76 U	0.72 U		
Arochlor 1260	5.4	4.6	5.8	4.5	4.0		

* - Where chemical analyses identified an undetected value for every individual compound/isomer then the single highest detection limit represents the group sum; and where one or more inidlvidual compounds/isomers are detected, only the detected concentrations were added to represent the group sum.
U - Indicates the compound was analyzed for but not detected at the given detection limit.

Although often found as laboratory contaminants, the concentrations found in samples W-000 and W-200 are not likely due to laboratory contamination. Concentrations of this order of magnitude can indicate the presence of plastic in the sediment sample. In fact, as noted above in Section 4-1, sediments sampled at Station W-000 were found to contain band-aids and other plastic materials, although they were not found at Station W-200.

Thus, the presence of these compounds does seem most likely to be associated with the outfall, as elevated levels were seen in stations adjacent to the outfall, and at lower levels at more distant stations. However, it is also possible that other sources have contributed to their presence in the sediments, as indicated by the presence of these compounds in sediments collected at the Ecology sediment monitoring station.

4.3 Bioassay Analyses Results

As described above, bioassay testing was conducted on six sediment samples (W-000, W-200, W-400, E-000, E-400, and E-800) and on reference and control sediment samples. Test species used were the echinoderm *Dendraster excentricus*, the amphipod *Ampelisca abdita*, and the polychaete *Neanthes arenaceodentata*. The full bioassay results report from Parametrix, including QA/QC information is found in Appendix B.

For the *D. excentricus* bioassay, all six sediments tested resulted in statistically significant ($p \leq 0.10$) greater combined percent mortality/abnormality when compared to the reference sediment. For the *A. abdita* test, none of the six sediments tested resulted in significantly ($p \leq 0.05$) reduced survival from the reference sediment. For the *N. arenaceodentata* bioassay, there were no survival effects, and none of the six sediments tested resulted in significantly ($p \leq 0.05$) lower growth compared to the reference sediment.

The results of the bioassay tests as compared to the SMS biological criteria are shown in Tables 4-8 and 4-9. The results have been shown for comparisons of the test sediment results with the reference sediment from Carr Inlet. All of the test sediments passed the acute toxicity amphipod and chronic toxicity polychaete bioassay tests. However, five of the six test sediments failed the acute toxicity echinoderm larvae test. It should be noted that the reference sediment collected in Carr Inlet did not meet the mortality performance standard for the amphipod test, although it did meet the mortality standards for the echinoderm and polychaete tests, as shown in Table 3-3.

The reference sediment mortality for the amphipod test was 28%, which is just over the performance standard of 25% mortality. As stated above, the test sediment results have been compared to the reference sediment for the amphipod test in Tables 4-8 and 4-9. If, however the test sediment results are compared to the control sediment mortality instead, as per a PSDDA/SMS clarification paper (Fox and Michelsen, 1996), the sediment sample from Station W-000 will fail the amphipod test, as the test sediment had 30% greater mortality than the control sediment. This is equal to the SIZ_{max} biological criterion. All other test sediments would still pass the amphipod test. Station W-000, immediately adjacent to the outfall, also failed the sediment chemistry SQS criterion for bis(2-ethylhexyl) phthalate.

It should also be noted that the *N. arenaceodentata* control sediment growth rate (0.68 mg/ind./day) did not meet the 0.72 mg/ind./day performance standard. This does not, however, invalidate this test but will require consultation with Ecology's sediment management personnel for approval on a case-by-case basis.

In looking at the results of the bioassay tests, in conjunction with the sediment chemistry data, it seems possible that the echinoderm larvae test failures for almost all the test sediments may be associated with the fact that all the test sediments had elevated levels of mercury. However, there is no direct evidence for linking the test failures to elevated levels of mercury. It is also possible

that the failure of the amphipod bioassay test for test sediments from Station W-000, (when compared to the control sediment), may be associated with the presence of elevated levels of bis(2-ethylhexyl) phthalate in that sediment sample. Again, there is no direct evidence linking the test failure to the elevated level of this compound. These results are consistent with the conclusions that 1) mercury contamination appears to be an area-wide problem in Sinclair Inlet, and 2) phthalate ester contamination of sediments immediately adjacent to the Bremerton WWTP outfall may be associated with the presence of the outfall.

5.0 CONCLUSIONS

Sediment samples from Stations located west of the WWTP outfall had relatively high concentrations of conventional parameters. Concentrations of O&G, TVS and TOC were highest at Station W-000, the station closest to the outfall. In contrast, total sulfides and ammonia concentrations were lowest at Station W-000, and highest at Station W-600.

Sediment samples from Stations located east of the WWTP outfall also had relatively high concentrations of conventional parameters, but at lower levels than those seen at the Stations west of the outfall. Concentrations of ammonia, O&G, TVS, TOC and sulfides were all highest at Station E-000, the station closest to the outfall.

Sediments collected from both the west and the east of the outfall were found to be predominately silty material in the 3.9 to 62.5 μ range (Tables 4-3 and 4-4). The samples had high percent fines (silts + clays) ranging from 71% to 93% in samples collected at Stations to the west of the outfall, and from 81% to 90% in sediments collected at Stations to the east of the outfall.

The fact that the sediment samples collected have predominately finer grain size material is associated with the correspondingly higher concentrations of TOC, TVS, ammonia and sulfides in the samples. Sediments collected from some of the Stations are likely to be somewhat anoxic as well, as evidenced by the high ammonia and sulfide concentrations, and the corresponding hydrogen sulfide odor noted above. Although most of the conventional parameters are highest at Stations closest to the outfall, high levels also occur in more distant Stations, which indicates that other sources of organic loading are likely present as well.

Of the eight metals analyzed, none exceeded the SQS or SIZ_{max} criteria in any of the test samples, with the exception of mercury which was found to exceed the SIZ_{max} criterion in sediments collected from every Station sampled. Mercury concentrations ranged from 0.843 to 0.96 mg/kg dry weight in sediments collected from Stations west of the WWTP outfall, and ranged from 0.829

to 0.89 mg/kg in sediments collected from Stations east of the WWTP outfall. The concentration levels are relatively similar, making detection of any significant trends in the data difficult. However, there appears to be a slight trend in that the highest or next to the highest concentrations are found in Stations W-000 and E-000 closest to the outfall, and the lowest concentrations are found at the Stations furthest away, W-800 and E-800.

As noted above in Section 2.2, mercury contamination has been found to be a widespread problem in all of Sinclair Inlet, and is not restricted to the area in the vicinity of the outfall, although mercury has been detected in the Bremerton WWTP effluent in the past. The mercury concentrations found in sediments collected in this current study are similar to those found in the Puget Sound Naval Shipyard study cited above (URS Consultants, 1994).

In addition, marine sediment monitoring data collected at Station 34 in Sinclair Inlet by Ecology (Figure 2-1), indicates that mercury is present at high levels (Table 4-5) in an area away from the WWTP outfall. In chemical analyses conducted on sediment samples collected from 1989 to 1995 at this station, concentrations ranged from 0.43 to 0.86 mg/kg. Thus, all of the available evidence points toward the conclusion that mercury contamination is an area-wide problem in Sinclair Inlet.

A majority of the organic compounds tested for were not detected in the WWTP outfall samples, and of those that were detected most had very low concentrations relative to the SQS criteria. Only two samples had measured concentrations of organic compounds which exceeded either the SQS or SIZ_{max} criteria, when normalized for TOC.

One sample (W-000) was found to have a measured concentration of 57 mg/kg (organic carbon) of bis(2-ethylhexyl)phthalate which exceeded the TOC-normalized SQS criterion but was below the SIZ_{max} criterion. This was the only organic compound found above detection limits in the sample. An additional sample (W-200) had a measured concentration of 5.6 mg/kg (organic carbon) of Butylbenzylphthalate which also exceeded the TOC-normalized SQS criterion (but

below the SIZ_{max} criterion). This was also the only organic compound found above detection limits in this sample.

As noted above in Section 2.0, Bis(2-ethylhexyl) phthalate has been found in the Bremerton WWTP effluent in the past. However, phthalate esters have also been found in concentrations similar to those seen at the stations sampled for this study at the Ecology sediment monitoring station away from the outfall (Table 4-5).

Although often found as laboratory contaminants, the concentrations found in samples W-000 and W-200 are not likely due to laboratory contamination. Concentrations of this order of magnitude can indicate the presence of plastic in the sediment sample. In fact, as noted above in Section 4-1, sediments sampled at Station W-000 were found to contain band-aids and other plastic materials, although they were not found at Station W-200.

The presence of these two phthalate ester compounds seems most likely to be associated with the outfall, as elevated levels were seen in stations adjacent to the outfall, and at lower levels at more distant stations. However, it is also possible that other sources have contributed to their presence in the sediments, as indicated by the presence of these compounds in sediments collected at the Ecology sediment monitoring station.

As described above, bioassay testing was conducted on six sediment samples (W-000, W-200, W-400, E-000, E-400, and E-800) and on reference and control sediment samples. Test species used were the echinoderm *Dendraster excentricus*, the amphipod *Ampelisca abdita*, and the polychaete *Neanthes arenaceodentata*. All of the test sediments passed the acute toxicity amphipod and chronic toxicity polychaete bioassay tests. However, five of the six test sediments failed the acute toxicity echinoderm larvae test.

It should be noted that the reference sediment collected in Carr Inlet did not meet the mortality

performance standard for the amphipod test, although it did meet the mortality standards for the echinoderm and polychaete tests, as shown in Table 3-3. If, the test sediment results are compared to the control sediment mortality instead, as per a PSDDA/SMS clarification paper (Fox and Michelsen, 1996), the sediment sample from Station W-000 will fail the amphipod test, as the test sediment had 30% greater mortality than the control sediment. This is equal to the SIZ_{max} biological criterion. All other test sediments would still pass the amphipod test. Station W-000, immediately adjacent to the outfall, also failed the sediment chemistry SQS criterion for bis(2-ethylhexyl) phthalate.

In looking at the results of the bioassay tests, in conjunction with the sediment chemistry data, it seems possible that the echinoderm larvae test failures for almost all the test sediments may be associated with the fact that all the test sediments had elevated levels of mercury. However, there is no direct evidence for linking the test failures to elevated levels of mercury. It is also possible that the failure of the amphipod bioassay test for test sediments from Station W-000, when compared to the control sediment, may be associated with the presence of elevated levels of bis(2-ethylhexyl) phthalate in that sediment sample. Again, there is no direct evidence linking the test failure to the elevated level of this compound. These results are consistent with the conclusions that 1) mercury contamination appears to be an area-wide problem in Sinclair Inlet, and 2) phthalate ester contamination of sediments immediately adjacent to the Bremerton WWTP outfall may be associated with the presence of the outfall.

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